Abstract

EFFECT OF FLY ASH ON THE OPTIMUM SULFATE OF PORTLAND CEMENT

Niemuth, Mark, D., Phd, Purdue University, December, 2012, Effect of fly ash on optimum sulfate of Portland cement. Major Professor: Jason Weiss.

Calcium sulfate is typically added to ordinary Portland cement (OPC) clinker during grinding to prevent flash set and to improve early-age strength development without causing additional volume instabilities. Recent changes to ASTM C150, Standard Specification for Portland Cement, have enabled greater flexibility in determining optimum sulfate levels in portland cement by not requiring ASTM C563, Approximation of Optimum SO3 in Hydraulic Cement Using Compressive Strength, to set sulfate target levels. ASTM C563 requires strength testing using only the hydraulic cement, which is not always indicative of the optimum sulfate for field use, since supplementary materials (e.g., fly ash) may be used by the concrete producer. Adding additional sulfate to account for the sulfate demand of fly ashes can enable an improvement in the early age strength for cement-fly ash systems and decrease in problems that may be attributed to OPC-admixture-fly ash incompatibility such as abnormal setting and strength gain.

This thesis provides experimental data on the strength development and heat release during early hydration for cement-fly ash systems with different sulfate levels. The thesis focused on high calcium fly ashes, but low calcium fly ash was also tested. It is demonstrated that some fly ashes have their own sulfate demand and when these ashes are used in cement-fly ash blends there is effectively an increase in the optimal sulfate level that could be used for the OPC. It is also shown that optimum sulfate determined by heat of hydration measured with isothermal calorimetry is similar to the optimum sulfate determined by compressive strength at 1 day.

Theories for the mechanisms that drive the differences in the sulfate demand in OPC are reviewed. These theories are adapted for OPC-fly ash blends and are outlined, tested and discussed. The testing of the theories is done by characterization of isothermal calorimetry, semi-quantitative x-ray diffraction (XRD), and pore solution ion concentration. This evaluation leads to some likely explanations of why some fly ashes affect optimum sulfate.

The fly ash C3A and SO3 have strong correlations to the increase in optimum sulfate along with freelime and soluble alkalis. The effect of the fly ash C3A can be explained by reacting with sulfate to form ettringite or monosulfate, by reacting with sulfate to form ettringite which contributes to strength at higher levels, or by retardation of the main alite hydration peak of the cement which requires additional sulfate to keep the sulfate depletion after the main alite hydration peak. The position of the sulfate depletion peak relative the main alite hydration peak has been correlated to optimum sulfate in the past and in this thesis.